

ON THE INFLUENCE OF MAGNETIC FIELD ON THE ABSORPTION SPECTRA OF LIQUIDS

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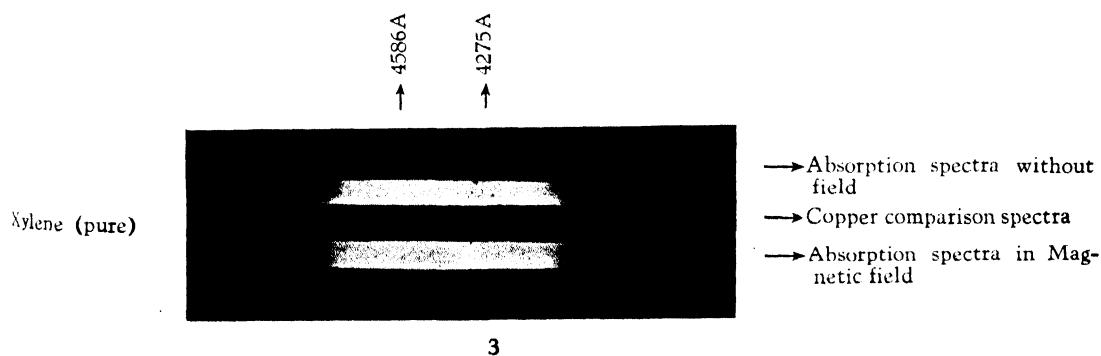
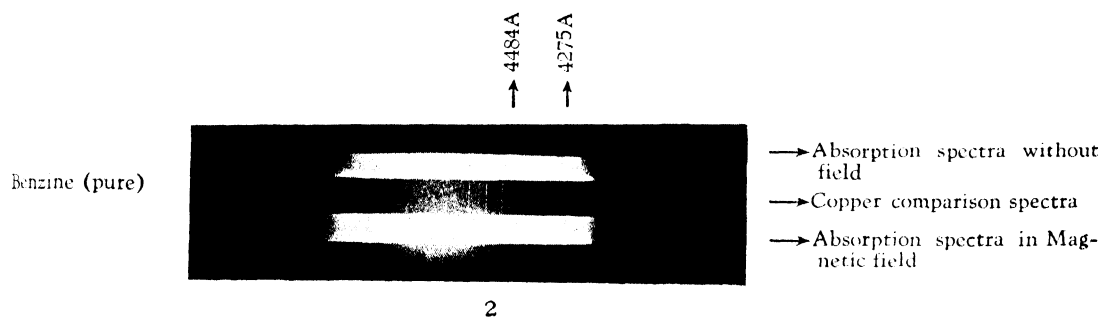
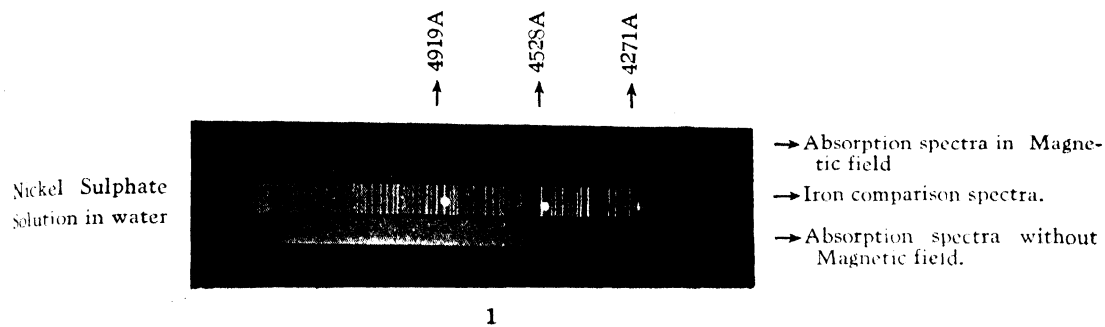
(Plate IV)

ABSTRACT. The width of the absorption band and the intensity of the transmitted light through an absorption cell containing solutions of crystals of $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$, $\text{CoSO}_4 \cdot 6\text{H}_2\text{O}$, $\text{FeCl}_3 \cdot 7\text{H}_2\text{O}$, MnCl_2 and pure liquids like benzene, xylene, etc., has been found to change under the influence of moderately strong magnetic fields. In the case of solutions of para-magnetic crystals, it was observed that the intensity of the transmitted light was less with field than without field. In the case of dia-magnetic liquids the intensity of the transmitted light was greater with field than without it. The magnetic field was of the order 13 kilo gauss.

During the study of the absorption spectra of para-magnetic solutions it was found that there were both a general diminution in the intensity of the spectra and a shift of the absorption edge as a result of application of the magnetic field. That the observed effect is undoubtedly a result of the influence of the magnetic field and not the spurious result of (i) any variation of the intensity of the source of light, (ii) temperature variations in the absorbing liquid, or (iii) any difference in the times of exposure, will be amply clear from the account of the experimental work which follows below. This conclusion is further confirmed by the observations on dia-magnetic liquids, of which the absorption spectra suffer an opposite change under the influence of a magnetic field.

The para-magnetic solution experimented upon consisted in the first instance of semi-normal ($N/2$) solutions of pure crystals of $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$, $\text{CoSO}_4 \cdot 6\text{H}_2\text{O}$, $\text{FeCl}_3 \cdot 7\text{H}_2\text{O}$ and MnCl_2 . The absorption-cell was a glass tube of diameter 1.40 cm. and 3.10 cm. long, closed at both ends by flat glass pieces cemented to it. This cell had a small hole at the top through which the liquid could be poured in and which was then closed with a small rubber stopper to provide against any loss by evaporation. The source of white light consisted of a frosted 220V, 100W, A. C. lamp having a sliding resistance and an accurate ammeter (Hartmann Braun, reading 0.05 amps per division) in series to check the constancy of the current through the lamp. The white light from the lamp passed through the absorption cell and was focussed on the slit of a constant-deviation spectrograph in which the spectrum was photographed, the cell was placed between the pole-pieces of a large and powerful Du Bois electro-magnet having a diameter of 9.5 cms. and a separation of 2.0 cms. The cell was thus in a fairly uniform field. The magnetic field was at right angles to the direction of transmission of light. The spectrograph was provided with a Hartmann slit, so that three spectra could be photographed on the same plate one above the other, the one above being without the magnetic field, the second one in the magnetic field and the lowest one with the field off again, the time of exposure in the three cases being exactly the same.

(i) To test for the constancy of the source of light, the transmitted light was focussed on a photo-voltaic cell and the photo-voltaic current was observed to

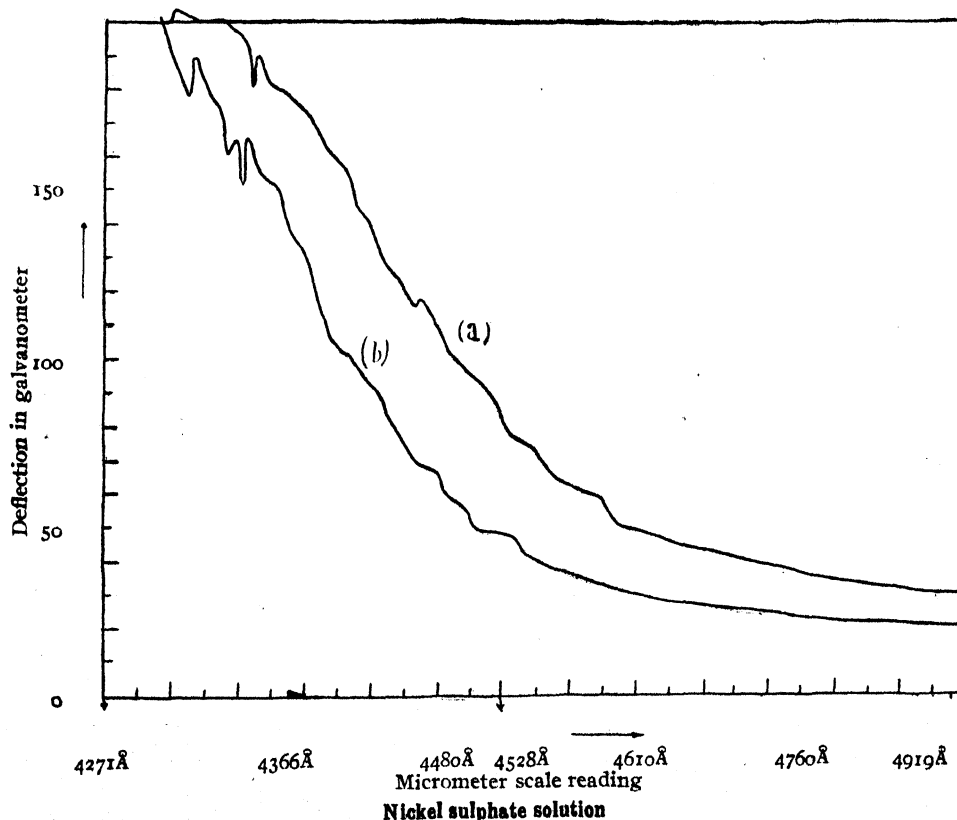


remain constant within $\frac{1}{2}\%$ over a period of 50 mins., the times of exposure, however, ranged from 10 mins. to 20 mins. only.

(ii) To study the influence of the time of exposure on the width of the absorption band, absorption-spectra were obtained by exposing the plates for periods ranging from 10 mins to an hour and no appreciable change in the width and character of the absorption edges was observed.

(iii) To test for the influence of temperature, the spectra were obtained when the solution was at room temperature 28.8°C . and again when it was heated through 7°C . No remarkable changes were observed. The temperature of the solution during the period of observation could not have varied by more than 0.5°C (as revealed by a thermo-couple immersed in the solution).

Plate III is a typical absorption spectra of a semi-normal solution of nickel sulphate, $7\text{H}_2\text{O}$ in distilled water at 28.8°C . The one below is without magnetic field (*i.e.*, in zero field); the central one is the iron comparison spectra and the uppermost spectrum is the absorption spectrum of the same solution under a uniform magnetic field of about 13000 gauss. Fig. 1 is a record of the intensity-distribution in the spectra as obtained by a non-recording Hilger microphotometer. Curve (a) of Fig. 1 gives the distribution when the field is on,



(a) Intensity distribution with magnetic field. (b) Intensity distribution without field.

FIG. 1

and curve (b) when the field is off. It can be seen that the solution gives an absorption band whose long-wavelength edge roughly corresponds to 4325\AA at about 28.8°C . A uniform field of 13000 gauss applied at right angles to the beam transmitted by the solution, pushes the long-wavelength edge of the band to the long wave side by about 58°\AA . It has been found that the change in the intensity of the absorption spectra varies with the strength of the applied magnetic field up to a certain extent, only above which it is fairly independent of the strength of the field. This indicates the existence of a saturation phenomenon. Further work is necessary to confirm this view. For a given magnetic field the change of intensity is not the same for all wavelengths. (Curves 'a' and 'b' of Fig. 1 and the table below will show this.)

TABLE I

Deflection of galvanometer

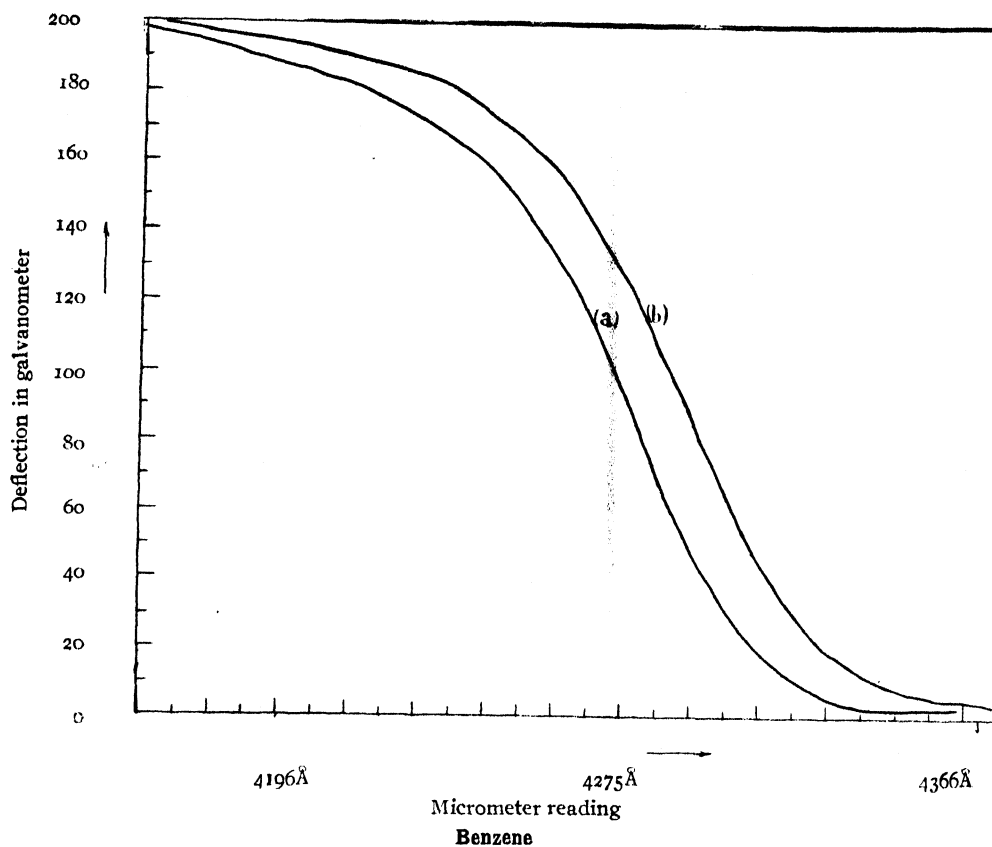
| Micrometer scale reading | When light passed through absorption spectra without any field | When light passed through absorption spectra in magnetic field |
|--------------------------|--|--|
| 2mm | 189 | 202 |
| 4mm | 160 | 196 |
| 5mm | 151 | 180 |
| 6mm | 129 | 172 |
| 8mm | 101 | 136 |
| 10mm | 64 | 109 |
| 11mm | 53 | 94 |
| 13mm | 40 | 71 |
| 15mm | 32 | 56 |
| 18mm | 26 | 42 |
| 20mm | 23 | 38 |
| 23mm | 21 | 32 |
| 25mm | 20 | 30 |

The change of the intensity of the absorption-band on the application of the magnetic field has been calculated by noting the change in the galvanometer deflections when light passed through the absorption spectra without and with magnetic field. In the particular case of nickel sulphate solution the ordinates at any reading of the micrometer scale corresponding to the two cases,—with and without magnetic field—have been read out, and the change in the intensity of the absorption-band has been calculated (see Fig. 1).

It may be observed that the change in the intensity of the band is maximum at about 4528\AA . (This has been found for NiSO_4 solution.)

Similar results have been obtained with $\text{CoSO}_4 \cdot 6\text{H}_2\text{O}$, $\text{FeCl}_3 \cdot 7\text{H}_2\text{O}$, etc.

In order to ascertain how far the solvent, *i.e.*, water in these cases, was responsible for the observed changes, the experiments were repeated with only distilled water in the absorption-cell. Up to a magnetic field of 13000 gauss, no appreciable change in the intensity of the spectra of the transmitted light through the cell was observed, there being no absorption band in the glass region.



(a) Intensity distribution with magnetic field.
 (b) Intensity distribution without field.

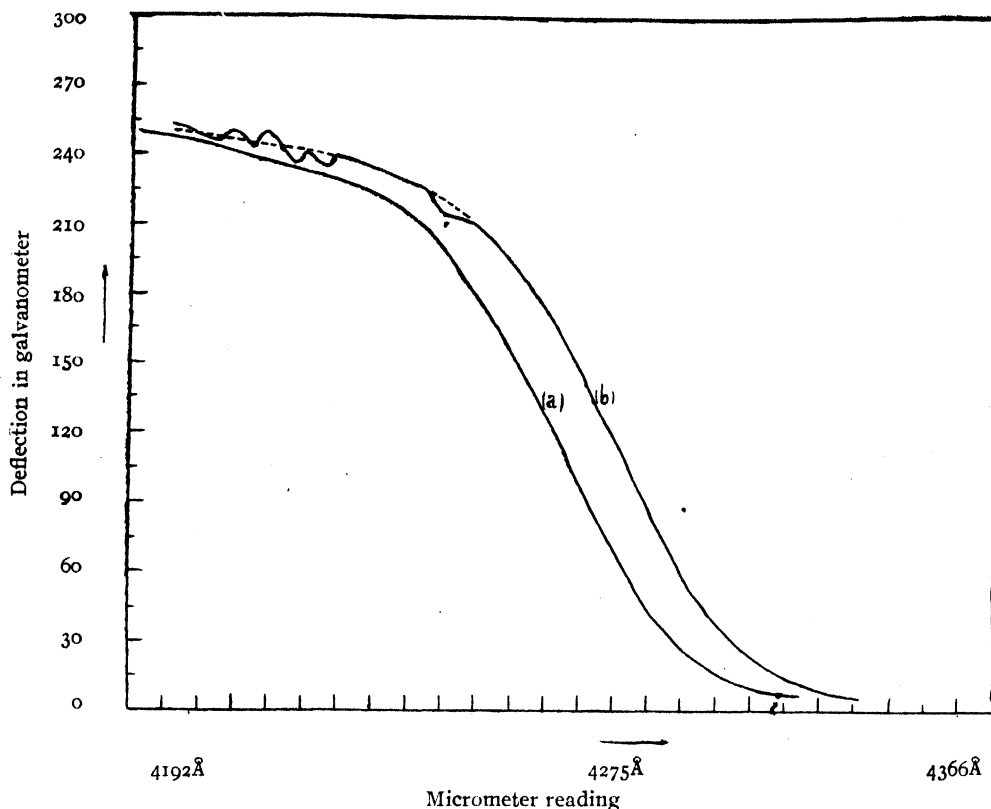
FIG. 2

It has been remarked that the dia-magnetic liquids like benzene, xylene, etc., show a similar effect but in the opposite sense. (For benzene see Fig. 2 and for xylene see Fig. 3.)

It has been observed that the application of the magnetic field shifts the absorption edge to the shorter wavelength side of the spectrum and produces a general increase in the intensity of the light transmitted through the cell.

Further work on a number of pure liquids like CS_2 , CCl_4 , aniline is in progress.

The effect discussed above appears analogous to the effect observed by Muller and others (1942), who have found that a magnetic field changes the intensity of the light transmitted through clear transparent colloidal suspensions of magnetite, rouge and other substances. It is hazardous at this stage to attempt a full theoretical explanation of the effects observed until more experimental data are made available. But there can be no doubt that the effect observed is a statistical effect. Under the influence of the magnetic field the para- or dia-molecules tend to attain a preferred orientation which is opposed by thermal



Xylene
 (a) Intensity distribution with magnetic field.
 (b) Intensity distribution without field.

FIG. 3

agitation until a balance is obtained. That this preferred orientation affects the transmission of light in one sense in the case of para-magnetic molecules and in the opposite sense in the case of dia-magnetic molecules indicates a certain space-asymmetry in the shape of the molecules or molecular groups. It may not be far from the truth to suppose that the variation of the resolved part of the cross-section of the oriented molecules or the molecular groups, perpendicular to the direction of transmission of the rays may be responsible for the changes in the intensity of the transmitted beam.

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REFERENCE

Muller, 1942, *Phys. Rev.*, **61**, 631.